World Urban Database & Access Portal Tool

Jason Ching & Sarav Arunachalam
CMAS @ Friday Center, UNC, 10/19/22

WUDAPT

& CMAS

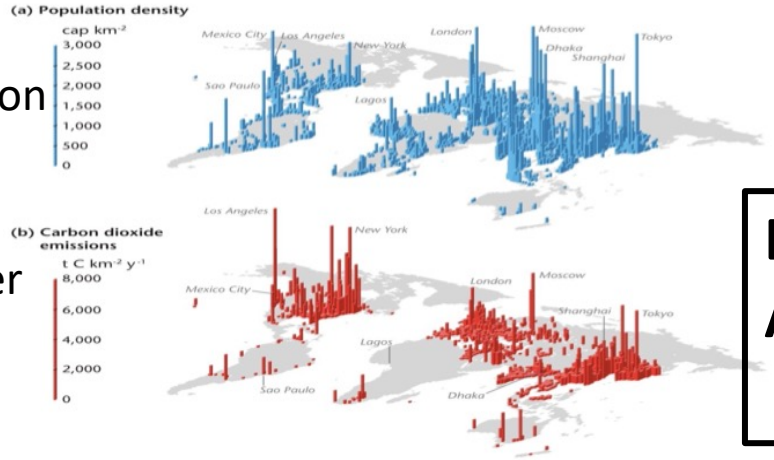
Part 1: Highlights of the WUDAPT Decade
Part 2: Exploring WUDAPT-CMAS Collaborations

An Urban Focus!

World Population
2000 > 1/2 Urban
2050 ~ 2/3 Urban
2100 > 3/4 Urban

Population

GHG, other Emissions



Enabling Urban Canopy Based Modeling, Worldwide
Addressing Intraurban Climate Change Risks
"Future City " Prospectives

From Baklanov CMAS 2022 Plenary

Modeling Tools needed!

Hazards and Risks in the Urban Environment

- Poor air quality and peak pollution episodes
- Extreme heat/cold and human thermal stress
- Hurricanes, typhoons, extreme local winds
- Wild fires, sand and dust storms
- Urban floods
- Sea-level rise due to climate change
- Energy and water sustainability
- Public health problems caused by the previous
- Climate change: urban emissions of GHG
- **Domino effect:** a single extreme event can lead to new hazards and a broad breakdown of a city's infrastructure



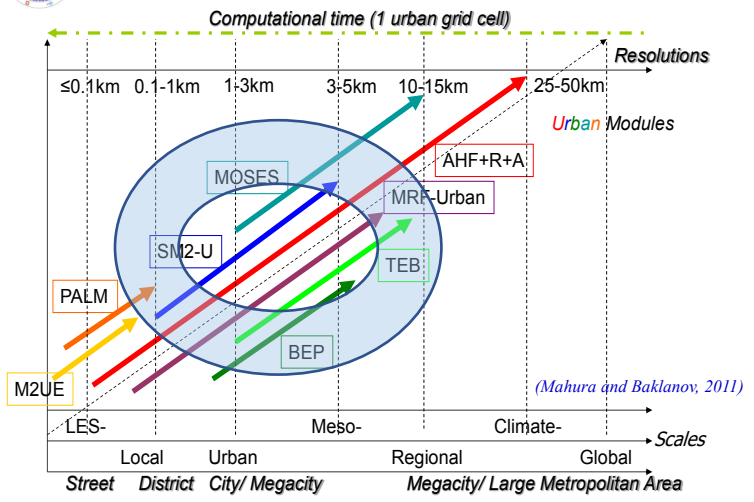




WMO OMM

Hierarchy of Urbanization Approaches

Urban canopy schemes for different type & scale models:



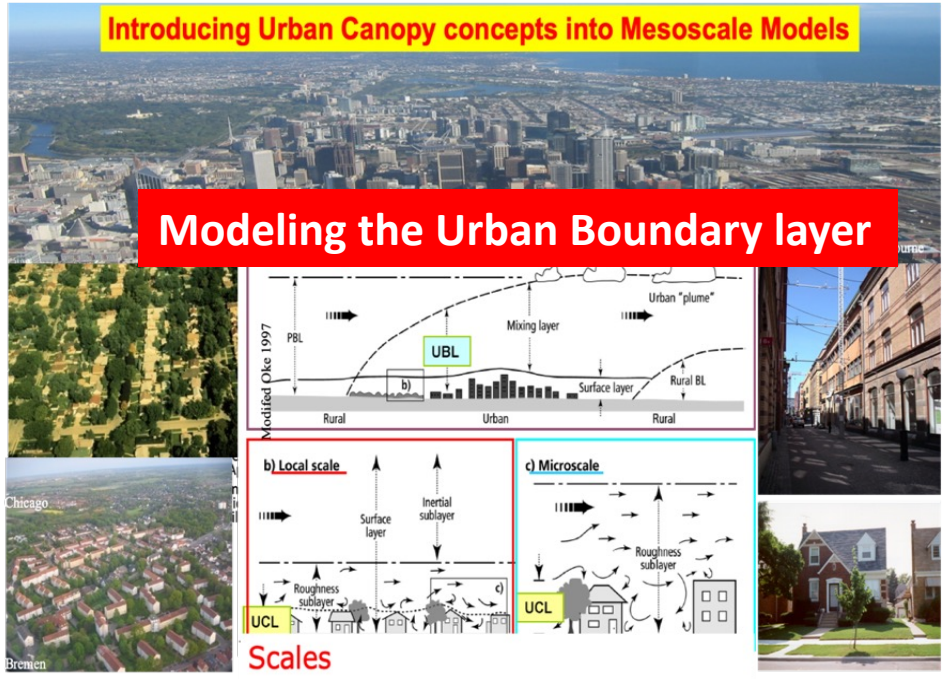
WUDAPT: A framework and infrastructure for "Fit for Purpose" urban applications

Urban areas are composed of aggregates of various 3-D morphological structures, impervious surfaces, and natural biota, responsible for creating canopy boundary layers.

Urbanization, population growth, and climate changes exacerbate a variety of risks.

Modeling treatments of canopy flows for Fit-for-Purpose (FFP) modeling can be treated with scale dependent sets of urban parameterizations (UCPs) and appropriate Form and Functional data.

WUDAPT'S goal is to generate such data on worldwide bases and an infrastructure for both generating appropriate data and supporting model implementation.

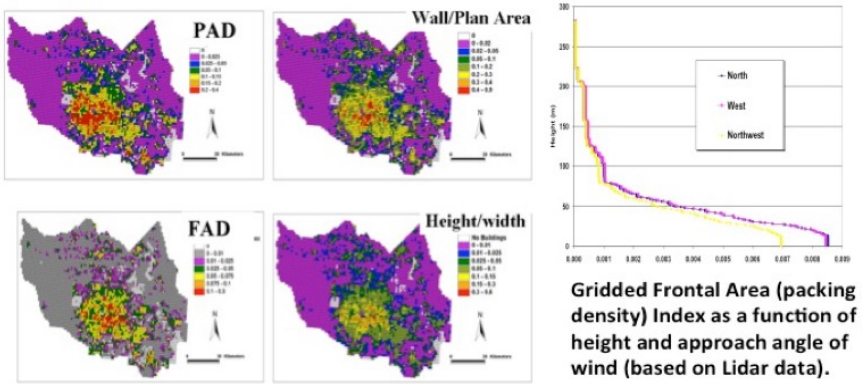


NOTEWORTHY!

Each grid has unique set of UCPs

Example UCPs in NUDAPT for Harris County-Houston

1 km gridded fields from processed digitized lidar data



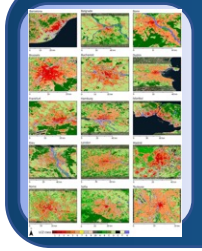
Gridded Frontal Area (packing density) Index as a function of height and approach angle of wind (based on Lidar data).

WUDAPT Strategic "Prospective" Approach

Current Strategy

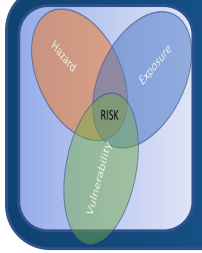
Level 0

- Local Climate Zone (LCZ) and UCP ranges
- Categorize city neighborhoods into LCZ classes
- Local Experts provide Training Areas
- Google Earth, Landsat and Saga
- City Specific to regional to Global LCZ Maps



Level 1

- More Precise UCP for each LCZ
- Focus on Form (e.g., building heights, street Width…) Function and Building Materials
- New Tools: DSC, UCP, UBEM
- Testbed as means to implementation



Level 2

- Fit for Purpose Applications &Analyses
- Links to various multiscale tools
- Current and future climate projections
- WUDAPT to Global Climate Models

BACKGROUND PERSPECTIVES

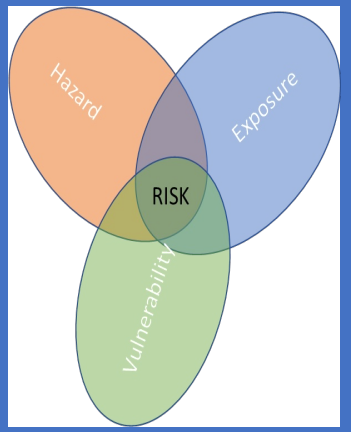
Prospective context: Future state projections
CMAQ, WRF, Emissions systems capable of Retrospective, Current and Prospective Modeling

RATIONALE and Synergisms

Issues& Impacts: enhanced risks, climate change, urbanization and AQ GHG Emission, Environmental Justice,
Risk on various jurisdictions, Local, State, Nation states, Global basis
Cost-benefit requirements of urban renewal and growth on jurisdictional scales

STRATEGIC THEMATIC APPROACH

WUDAPT, Tools, Portal, and Testbed explore "What if" Future City Design (Level 2)
Rationale, Synergism of climate change and urbanization on from neighborhoods to global basis
CMAS explore scoping studies based on Future City options



Level 2a, Details

uWRF Application and Analyses
Links to UMEP, SUEWS, Envi-Met
Energy and GHG Emissions
WUDAPT TO GCMs/UCLM5
Future Cities Perspectives

Urban (1–10) and natural (A–G) Local Climate Zone definitions
(adapted from Table 2 in Stewart and Oke *et al*. 2010

Level 0 Paradigm:

Generate maps based on Local Climate Zone Classification Scheme and Lookup Table of UCPs for each LCZ class

UCP values associated with LCZ classes

LCZ	λ_B	λ_I	λ_V	H	SVF	AHF	IMD
1. Compact high-rise	40–60	40–60	<10	>25	0.2–0.4	50–300	>80
2. Compact midrise	40–70	30–50	<20	10–25	0.3–0.6	<75	>70
3. Compact low-rise	40–70	20–50	<30	3–10	0.2–0.6	<75	>60
4. Open high-rise	20–40	30–40	30–40	>25	0.5–0.7	<50	50–80
5. Open midrise	20–40	30–50	20–40	10–25	0.5–0.8	<25	50–80
6. Open low-rise	20–40	20–50	30–60	3–10	0.6–0.9	<25	40-90
7. Lightweight low-rise	60–90	<20	<30	2–4	0.2–0.5	<35	>60
8. Large low-rise	30–50	40–50	<20	3–10	>0.7	<50	>70
9. Sparsely built	10–20	<20	60–80	3–10	>0.8	<10	10-40
10. Heavy industry	20–30	20–40	40–50	5–15	0.6–0.9	>300	>40
A. Dense trees	<10	<10	>90	3–30	<0.4	0	<20
B. Scattered trees	<10	<10	>90	3–15	0.5–0.8	0	<20
C. Bush, scrub	<10	<10	>90	<2	0.7–0.9	0	<20
D. Low plants	<10	<10	>90	<1	>0.9	0	<20
E. Bare rock or paved	<10	>90	<10	<0.25	>0.9	0	>90
F. Bare soil or sand	<10	<10	>90	<0.25	>0.9	0	<20
G. Water	<10	<10	>90	–	>0.9	0	<20

https://doi.org/10.1371/journal.pone.0214474.t001

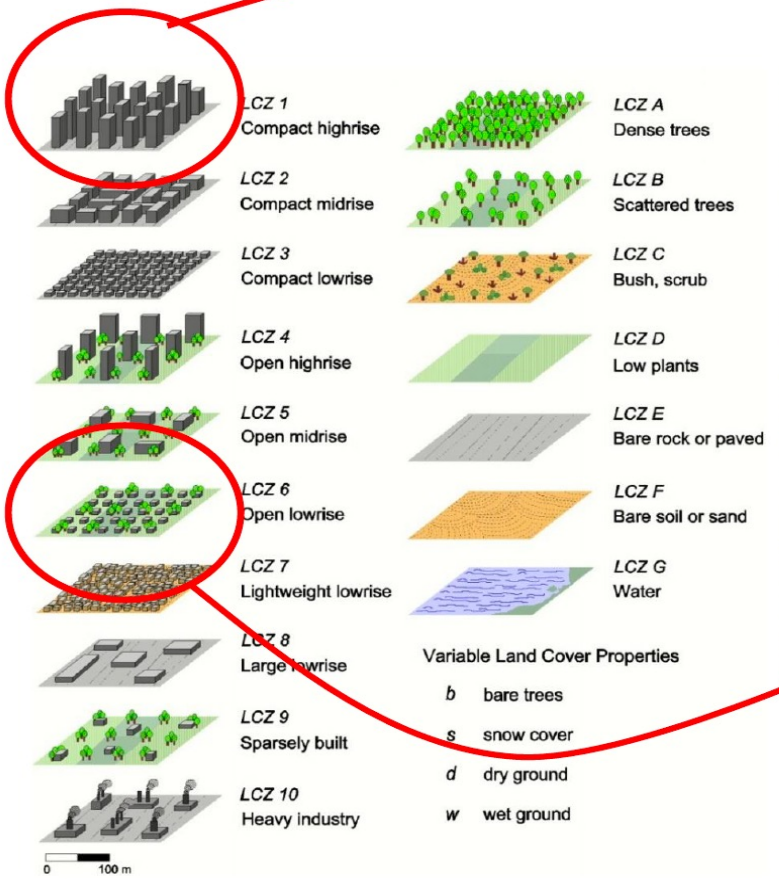
LCZ Methodology

Local Experts identify set of Training Areas for each city

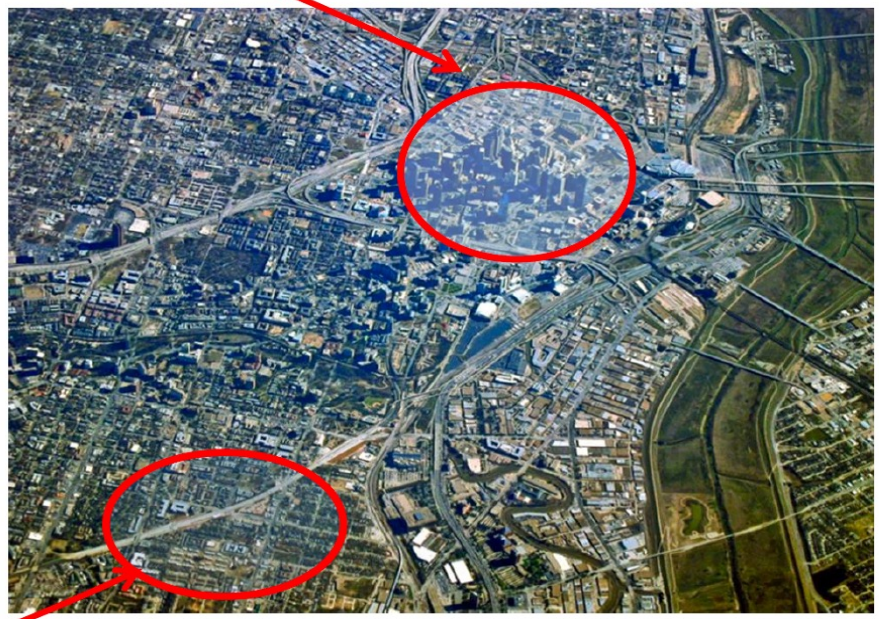
Create Maps based on TAs.

Create maps based on LCZ Generator

Level 0 WUDAPT data



Stewart & Oke, 2012



The Local Climate Zone (LCZ) classification provides a scheme for describing the basic physical geography of cities suited to further data gathering.
It can be used as a *sampling frame* to gather more detailed urban data (e.g. building materials, cooking fuel, etc.) at more detailed spatial scales.

Lookup Tables provide Range of Model Parameters Values associated with Local Climate Zones from WUDAPT Level "0"

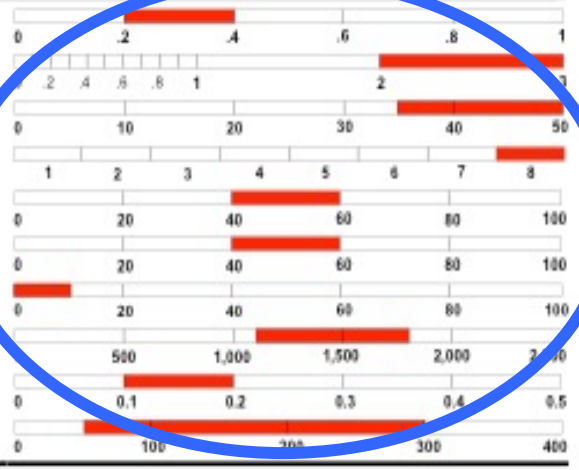
LCZ 1 COMPACT HIGHRISE

DEFINITION

Form: Dense and irregular mix of tall buildings to 10s of stories. Buildings close-set, free-standing. Sky view from street level significantly reduced. Streets paved. Buildings of steel, concrete, and glass construction. Little or no pervious ground. High space heating/cooling demand. Heavy traffic flow. ***Function***: Commercial (office buildings, highrise hotels); residential (apartment towers). ***Location***: City core ("downtown," central business district). Periphery (highrise subcentre, highrise sprawl). ***Correspondence***: UCZ1 (Oke, 2004); Dc1 and Dc8 (Ellefsen, 1990/1).

ILLUSTRATION

PROPERTIES



LCZ 6 OPEN LOW-RISE

DEFINITION

Form: Small buildings 1–3 stories tall. Buildings detached or attached in rows, often in grid pattern. Sky view from street level slightly reduced. Construction materials vary (wood, brick, stone, tile). Scattered trees and abundant plant cover. Low space heating/cooling demand. Low traffic flow. ***Function***: Residential (single or multi-unit housing, low density terrace/row housing); commercial (small retail shops). ***Location***: City (medium density); periphery ("suburbs"). Commuter towns. Rural towns. ***Correspondence***: UCZ5 (Oke 2004); Do3 (Ellefsen 1990/91).

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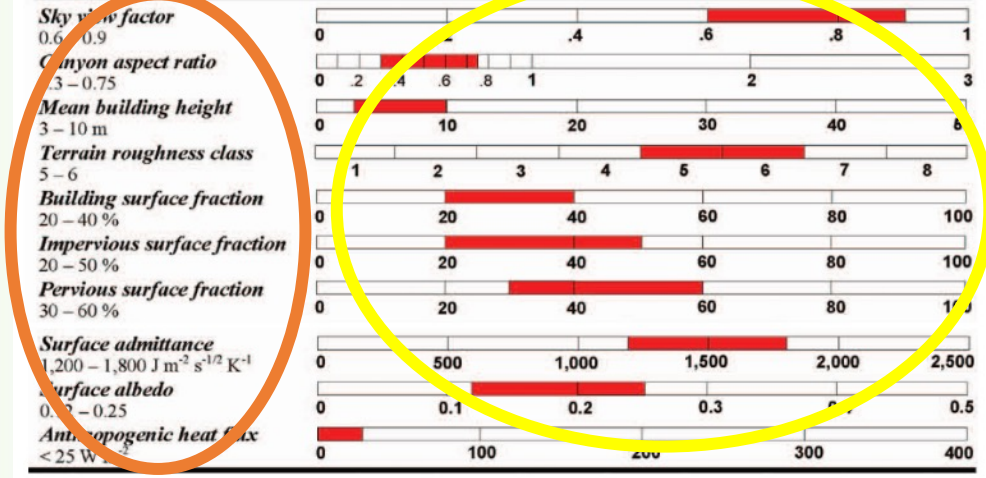

The WUDAPT Decade

JKS. Ching, G. Mills, B. Bechtel, M. Demuzere, D. Aliaga, C. Ren, M.M.F. Wong, D. Niyogi, M. Neophytou, A. Middel, I. Stewart, L. See, S. Arunachalum, Y. Shi

IAUC Community @ICUC-9, Toulouse, France, 2015

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HUMINEX (Quality)

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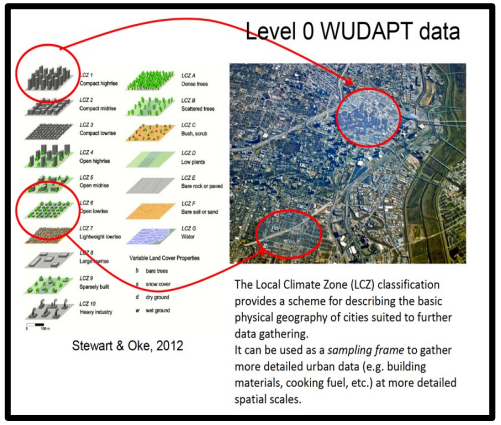
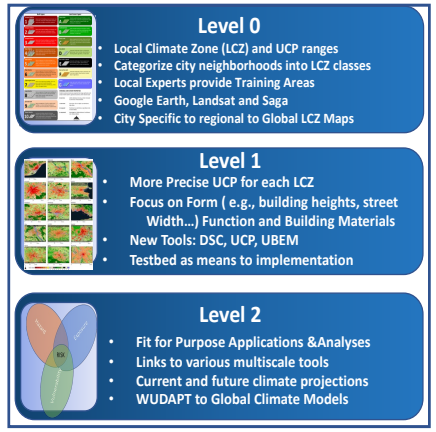
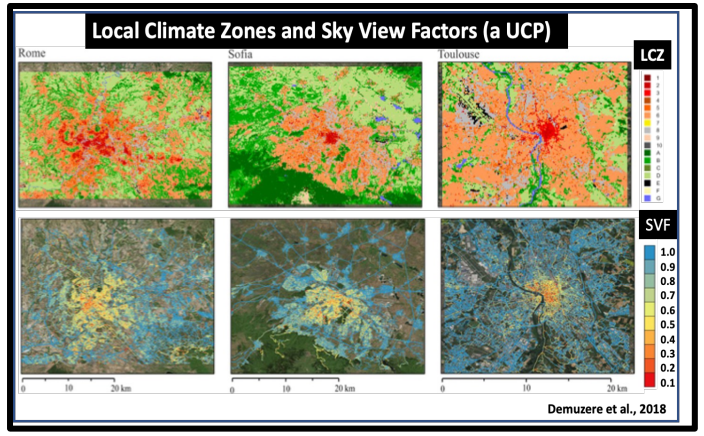
Proposed LCZ City-Regions-Global maps

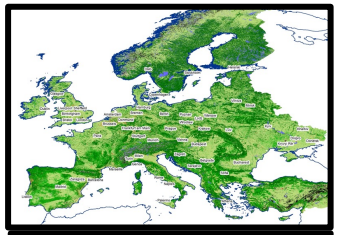
2020 – 2022
AMS-BUE Boston
DSC, UBEM Tools
Regional Maps,
LCZ Generator, UCP Tools
Global LCZ maps

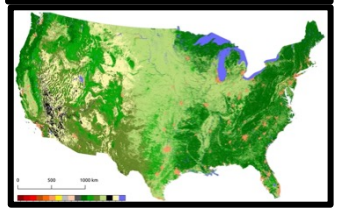
Future
Level 1&2 Testbeds
Fit for Purpose Applications
- Intraurban WX, AQ
- Sustainability
- Urban Planning

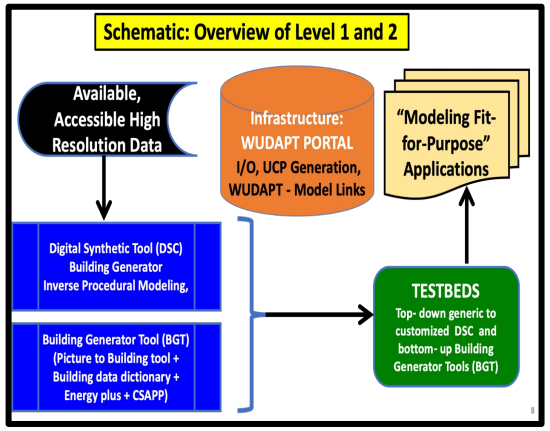












WHY?
- Enhanced risks, Climate Change
- Urban population exceeds 50%
- Need for Urban Services
- Science-Based Advanced Modeling Systems
  - Weather, Air Quality, Climate,
  - Energy, GHG systems
  - Future Cities Modeling

KEY PARADIGMS, APPROACHES
- Universal LCZ foundation
- Multiple Community based collaborations
- Innovation and methodology driven
- Strategic Hierarchical approach,
- Advanced Quality Assurance
- Dynamic LCZ change Implications
- Testbeds for
  - Methods evaluation
  - Fit for Purpose (FFP)Applications

MAJOR OUTCOMES
- Unique City Specific LCZ maps
- LCZ Generator tool
- Intra-urban Baseline and Prospective Studies capabilities
- Regional LCZ Maps
- Building to block scale Form and Function details
- Global LCZ map
- Addressing Climate Change Risks

GET INVOLVED!
- Testbeds
- UCP Advances, refinements
- FFP Applications, Air Quality
- Future cities
- Global Climate data infrastructure

SUMMARY AND HIGHLIGHTS: WUDAPT Decade

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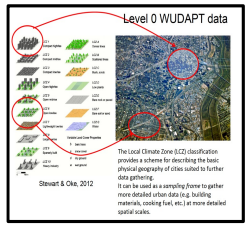

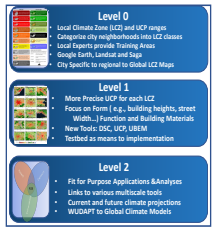

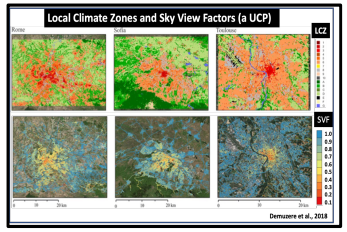

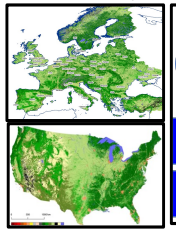

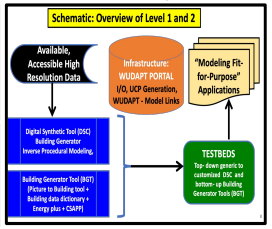

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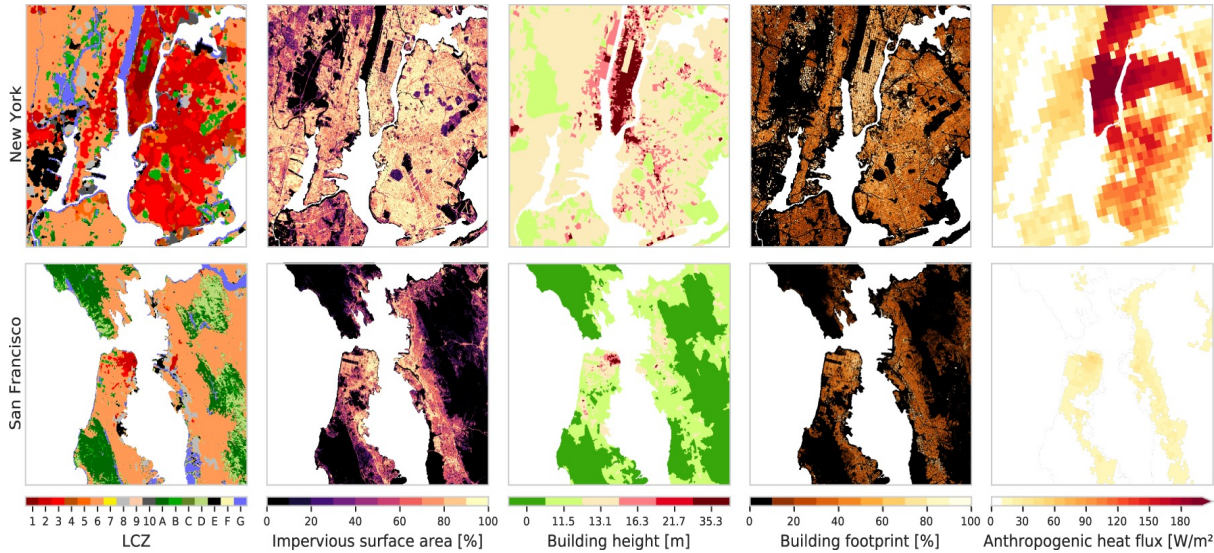
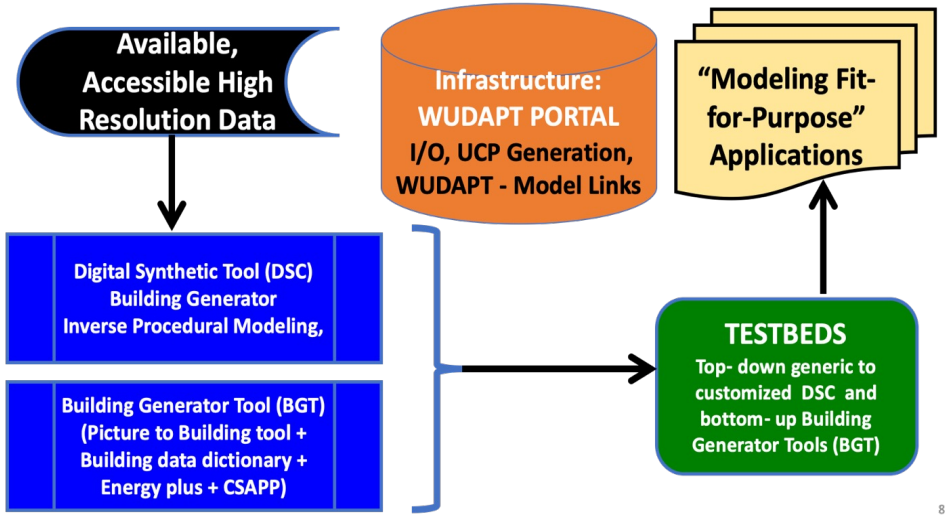
Maps of LCZ and UCPs from regional/global maps

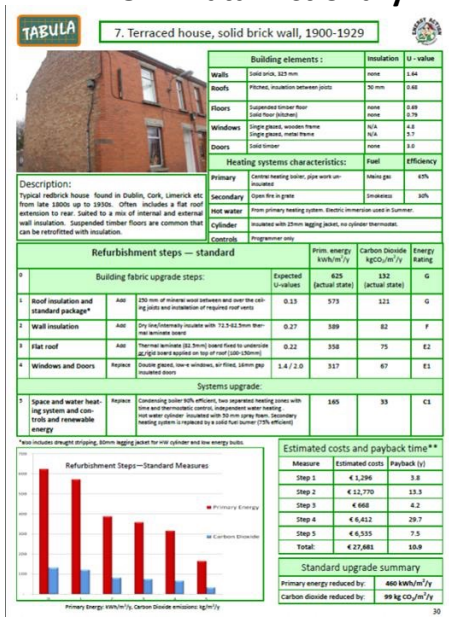


- Initiative of the IAUC (Int'l Association of Urban Climate) 2012-Present
- WUDAPT: The UCP modeling input gap has been addressed
  - Initial enterprise: UCPs from Local Climate Zone (LCZ) Paradigm
  - Achievement: LCZ/UCP maps for major cities around the world available on WUDAPT Portal
  - Significance: Provision for myriad of urban FFP UCP based modeling applications now possible, WORLDWIDE
  - >300 relevant articles published
- Special Issue of Urban Climate "the WUDAPT Decade" FFP Applications templates. Deadline 12/2023
- Critical next step: identify and explore opportunities for CMAS Community Collaborations **(Testbeds)**

Schematic: Overview of Level 1 and 2



TABULA Data Dictionary



Prototype UBEM

Building Archetype

Rating		UMI	
kWh/m2/y r	kgCO2m2/y r	kWh/m2/y r	kgCO2m2/y r
377	104.2	372	102.8
480	132.6	410	113.3
369	102	396	109.4
382	105.6	398	110
350	96.7	388	107.2
366	101.1	383	105.8
384	106.1	409	113
425	117.4	399	110.2
377	104.2	383	105.8

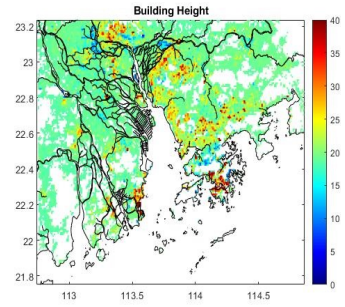
Level 1&2: Computing scale dependent Urban Canopy Parameters (UCPs) given digitized urban morphology from High-Res Google type satellite imagery based on WUDAPT's Digital Synthetic City (DSC) tool

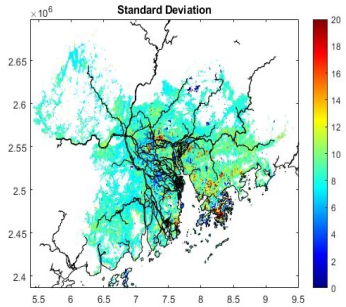
DSC digitizes urban features

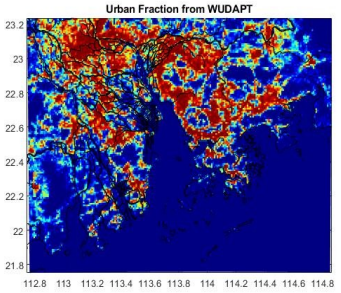
Therefore: UCPs can be generated for each and all grids in domain & Grid size is a user choice

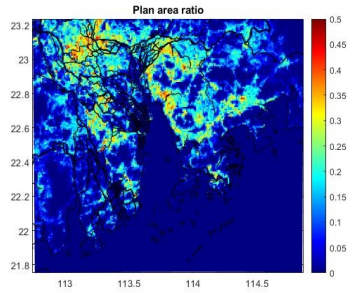
Examples using Level 1 UCP Tool

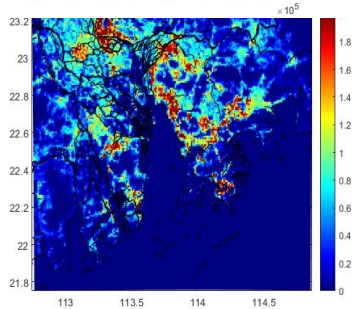
- Building Height
- Plan area ratio
- Building surface to plan area ratio
- Standard deviation of building heigh
- Urban Fraction









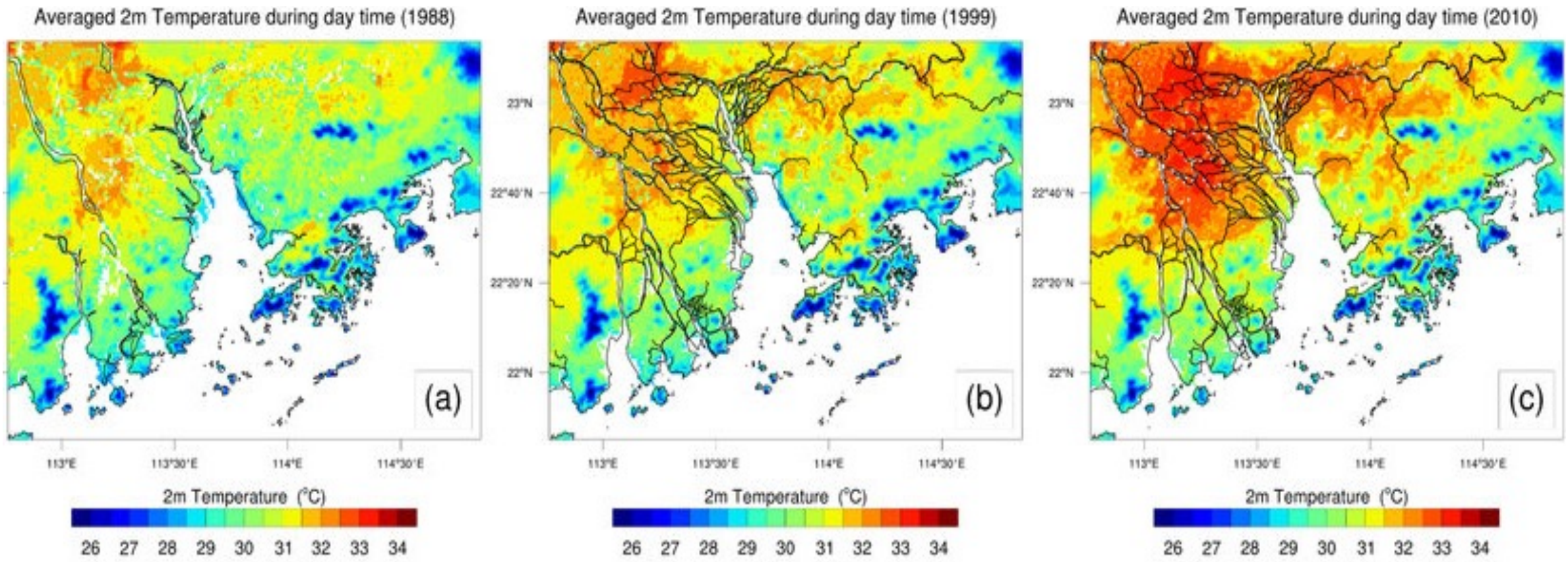


WUDAPT tool for generating level 1&2 form-based UCPs (courtesy of M. Wong)

Part 2: OVERVIEW of WUDAPT & CMAS collaborations

- **Urbanization:**
  - **Population of Urban Areas >50% in 2200; Projected 75%^ in 2275**
  - **Major source of air polluting and GHG emission**
- **WUDAPT (2012-22-00) LCZ-UCP capable of simulating Wx at urban (1km) and intraurban (100m) scales**
  - **IAUC and AMS Community collaborations**
  - **Generates maps of LCZ and UCPs (Note that such maps change with time (see wrf modeling for PRD))**
  - **City maps worldwide has unique LCZ, UCPs signatures**
  - **Preprocessor to CMAQ, WRF-CHEM, etc**
- **Model applications**
  - **Climate Change induced Extreme Risks**
    - **Extreme heat, Urban flooding modeling, Drought**
    - **Regional contexts**
  - **Policy: Environmental Justice issues an EPA-ORD Priority**
  - **Urban growth Projections and Urban planning, Scenerios Design Sustainability, Resilience,**
- **Modeling links (Fine scale AQ to street level exposure)**
  - **UMEP**
  - **Envi-Met**
  - **ADMS to Exposure modeling- link WUDAPT to Street level exposure modeling (ADMS, SinG…..)**
- **Anticipated Climate modeling**
  - **Ready to engage with Global LCZ map**
  - **Incorporate into EASM-UCLIM pending**
  - **RCP projections**

uWRF daytime 2.5 m temperature simulation showing urbanization effect in the PRD region between1988, 1999 and 2011 based on WUDAPT. WRF modeling setup identical except for the LCZ generated for the different years.



Jason Wai PoTse, et al., 2018: **Investigation of the meteorological effects of urbanization in recent decades: A case study of major cities in Pearl River Delta, Urban Climate**

Suggested studies evaluating and utilizing WUDAPT advances relevant to CMAS community

Summary perspectives for CMAS Relevance to Air Quality

- **FFP urban and intraurban AQ modeling applications**
  - **Demonstrate and explore application as design templates of applying CMAQ at local scales**
  - **Running CMAQ with MPAS, or regular grid system**
  - **Performing SinG-type modeling for AQ exposure modeling**
- **Siting WX and AQ observations in context of LCZ**
- **Prospective of future city design**
- **Design Applications for supporting Environmental Justice**
- **Incorporating WUDAPT into GCMs**
- **Training for links to running WUDAPT to AQ FFP applications**
- **Advancing further discussions vis WUDAPT Forum**

uWRF To Climate, Air Quality

- **Preprocessor to CMAQ**
- **CMAQ & CMAS Regional and intra- Urban Assessments**
  - **Smoke and dust transport**
  - **Environmental Justice**
  - **Extreme event (Heat, Flooding…_)**
  - **Urban planning Support**
    - **Urban design (Future Cities)**
    - **Greening scenerios**
    - **Urbanization**
- **UBEM Emission characterizations**
  - **GHG**
  - **Anthropogenic Heating**
- **Street level Exposure Modeling**
  - **ADMS Prototype**
  - **SinG Prototype**

Comments and Questions !

- For Further Details www.wudapt.org
- Consider contributing the SI Urban Climate for prototype FFP applications
- Contribute to methods development and testing
- Become testbed collaborators